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There are two questions I want to address in this paper.

1) What is the evidential status of ~~hypothesized~~ entities such as quarks and theories such as QCD? In particular is ~~are their special~~ there a special problematic associated with just these entities and this story?

But that leads to the second question of a more general nature

2) What is the evidential status of any theoretical entities and their properties and relations as encoded in some area of theoretical discourse, in ~~theoretical~~ physics?

The second question touches on a central concern of general philosophy of science.

But let me start with the first question.

For

quarks just came into the physics vocabulary with the fundamental representation of the  $SU(3)$  symmetry introduced into particle physics in the early 1960s by Murray Gell-Mann and Yuval Ne'eman.

The actual ~~particles~~ <sup>associated</sup> were represented with terms of higher-dimensional representations of the  $SU(3)$  symmetry, just as the octet, its original eight-fold way, the quarks were at first a somewhat shadowy substratum for backing up the particles actually observed in

\* 9 say 'photography' focus



one could say that from the point of view of an algebra of currents, and take this seriously and discard the quarks - throwing away the ladder after making the ascent so to speak.

But then in the late 1960s came the deep inelastic electron scattering experiments at SLAC, the verification of Bjorken scaling, and the immediate interpretation in terms of part-like constituents, the parton model of the nucleus. It was also a small step to identify the partons, which in a sense are called directly 'see' with the highly conjectured quarks.

But with the quarks came the theory of quark interactions, the colour degrees of freedom, the 'gluon fields' and the whole apparatus of non-Abelian gauge theory in the now familiar Standard Model, asymptotically the electroweak theory of Weinberg and Salam, with the quantum chromodynamics of strong interactions.

And there were immediate successes in terms of empirical predictions that quantitatively verified departures from crude Bjorken scaling, the production of jets and so on.

So did physicists believe in the theory? (I will come to philosophers later). Well not exactly, it was not that the theory was empirically refuted for from it, but there were theoretical

new ideas

A

thinks there are all the same  
 but they don't understand, and  
 the machine mechanics —  
 the machine mechanics are  
 the same, but the  
 the same, but the  
 the same, but the



the demonstration - last week on the  
theory of strong interactions.  
\* ~~Smoking~~ ~~the~~ ~~business~~ ~~of~~ ~~infinite~~ ~~renormalizations~~ ~~required~~ ~~of~~ ~~course~~ ~~in~~ ~~so~~ ~~called~~ ~~renormalizable~~ ~~theories~~.

Most physicists regard renormalized theories as some sort of "effective theory", hiding the detail of the 'true' theory behind renormalized parameters, whose values were to be later found experiment.

Next, there was a sense of ad hocery in the number of adjustable parameters in the standard model, not the curious role of the Higgs particle in the electro-weak sector.

Then finally, physicists were drawn by the holy grail of grand unification, trying to leptons and quarks in a single scheme. Grand unified theories generally predicted the ~~instability~~ ~~of~~ ~~the~~ ~~proton~~ via the ~~conversion~~ ~~of~~ ~~quarks~~ ~~into~~ ~~leptons~~.

This has not so far been observed, but most physicists expect that it is an allowed process, although on a very long time scale. To that extent they do not believe in the GUT as the final theory.

Finally there is of course the whole question of incorporating gravitation in a theory of everything and the recent surge of enthusiasm for supersymmetry theories.





"Do physicists believe in classical mechanics?" The answer is yes for certain limited purposes of theoretical modelling of phenomena but not in the sense that it is a serious candidate for being the being dead right - the final answer in strong interaction physics.

[ But what about the quarks themselves? This is often stated to be a special problem here associated with the phenomenon of quark confinement. In the past the real has been proved well the manifest electrons, atoms, nuclear and so on could be dealt with simply in their free state and then elegantly explained by an elaborate Aufbau principle putting the single constituents together. This is the classical method of analysis of understanding complex whole in terms of their simple constituents. But as a sense the quarks are a sort of counterexample, since they cannot be separated from their partners.

[ But this stress on making real entities manifest is a somewhat misleading of what we mean by manifest. The deep inelastic scattering experiments manifest the quarks just as surely, as holding them, 'one at a time',





to speak. Direct observation is  
actually pretty 'reliable', so far  
as particle physics is concerned.  
We see particles by actual seeing  
what they can do. Producing short  
class tracks in bubble chambers, firing  
off spark chambers and so on.

Let me now turn to what a  
philosopher might say on reading  
the preceding paragraphs, what are  
supposed to represent the 'means  
of physicists'. I will simply turn  
to my second question, what has  
a much broader focus, what sort  
questions are there?

Is what some should not believe  
in, secret at all?

There is a broad spectrum of  
what I may call isms and schools  
in answering such a question, which  
fill the pages of philosophical paragraphs  
and journals.

At one end of the spectrum there are  
the relativists, the anti-realists, the  
irrationalists. At the other end, are  
the realists, the objectivists, the  
champions of 'scientific rationality'.  
And there is pretty well every shade  
in between.

Let me first sketch the extremes and  
then look at the compromises.  
But as we shall see, the compromise  
positions are gradually <sup>grad to be</sup> constant, and





First the 'relativist' denies that there is an objective fact of the matter about any area of discourse, whether it be natural science, ethical questions, or even logic and mathematics. There is no ~~an~~ Archimedean point, no God's-eye perspective, from which truth in ~~all~~ sense of incommensurable with what is actually the case, makes any sense of any claim to 'grasp reality' as it is in itself. The Cartesian long on - red, is just 'a metaphysical conceit',

Here, say the relativists, cannot  
 we achieve knowledge of the  
 not matter by what they  
 know as 'evidences', or as the  
 basis of evidence derivation, which,  
 they say is conditioned by idealist  
 presuppositions that it can provide no  
 real foundation for knowledge so  
 we are left without sense of having the  
 important truth about things and they  
 say 'where and when'.  
 This they say is motivated by having  
 to show that it is not, in fact, the  
 most calculated of the idealist  
 and is the one which makes  
 the most sense of things and  
 which is the most consistent, or







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control concerns of some idealist enquirers  
idealized enquirers, but how can we  
tell what makes an idealist enquirer?  
I could it be, cynically, just someone  
who ultimately comes 'to agree with  
you yourself'. But the fall to  
extreme relativism is really impossible  
to resist. So the trick of not tarrying  
into a relativist, is not to allow  
the first subtly allowing move, of  
going soft on truth. For quarters, it may  
not matter so much, but in everyday  
life I believe it really does make  
a difference whether we believe in mystical  
forces or against it in witchcraft and spells  
and I know for sure which jetliner I  
want to travel in, the realists or  
the relativists!

So let us start again at the other end, and ask <sup>relating to the macroscopic world</sup> ~~the~~ <sup>whether</sup> realists about <sup>yes</sup> ~~the~~ matter of everyday life? And if the answer seems to be <sup>yes</sup> ~~yes~~ let us make the reverse slide, if I can put it like that from a robust realism about tables and chairs to a definitely more agnostic realism, but realism all the same, about quarks and G.C.D. I believe the physicists just feeling for this thing is probably right (that is another question for you) and I totally reject the wishy-washy but ultimately



Sweden  
a my personal experience in my  
mother's work.

...constructivist...  
...is imputed to my socio-economic environment,  
I will simply respond: 'pfft, no!':

